



CHEMICAL EMERGENCY PREVENTION & PLANNING

Newsletter


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US EPA Region 10

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This issue features:

Pressure Vessels: Rupture Hazards and Prevention

Images of Pressure Vessel Failures



The scene following a vessel failure and fire. The vessel ruptured due to overpressurization, releasing flammable material which then ignited. Four workers were killed.



An internal non-code weld had weakened the shell of this vessel. The tank exploded causing the release of anhydrous ammonia to the atmosphere.



This vessel exploded killing one operator and triggering the release of aqua ammonia. The tank had no relief device for overpressure protection, nor did it have basic process control or alarm instrumentation.



(Photo of tank before explosion). The propane tank that caught fire and exploded after a vehicle plowed into the tank's unprotected piping. The explosion killed two volunteer firefighters and injured several emergency responders.

CEPP Newsletter

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Rupture Hazard of Pressure Vessels

Problem

Improperly operated or maintained pressure vessels can fail catastrophically, kill and injure workers and others, and cause extensive damage even if the contents are benign.

Example of Accidents

Three workers were killed and a number of others were injured when a high-pressure vessel containing air and water ruptured. The vessel that ruptured was originally designed with a working pressure of 1740 pounds per square inch (psi), but was operating between 2000-3000 psi. After a number of years of service, the vessel developed a pin-hole leak. The leak was repaired but not in adherence with recognized codes. About a month later, the vessel failed catastrophically at the weld area. The vessel ripped apart and rocketed through the roof. Major pieces of shrapnel weighed from 1000 to 5000 pounds. Some pieces were thrown a half mile away. Fortunately, people on a nearby highway and a nearby commuter railway narrowly missed injury. Damage to the plant was extensive and a portion of the state was without phone and electrical services for many hours.

Hazard Awareness

This accident demonstrates the potential danger of pressure vessels if they are not properly designed, constructed, operated, inspected, tested, or repaired. The higher the operating pressure and the larger the vessel, the more energy will be released in a rupture and the worse the consequences. It should be emphasized that the danger exists even if the vessel contents are not flammable, reactive, or explosive. In the case above, a vessel containing only water and air ruptured and released great energy. Had the contents of the vessel been flammable and/or toxic, the consequences would probably have been magnified.

Factors in Pressure Vessel Failure

The following conditions and factors have played major roles in pressure vessel accidents:

- ❖ Operation above the maximum allowable

working and test pressures.

- ❖ Improper sizing or pressure setting of relief devices.
- ❖ Improper operation of relief devices due to faulty maintenance and failure to test regularly.
- ❖ Failure of the vessel due to fatigue from repeated pressurization, general thinning from corrosion or erosion, localized corrosion, stress corrosion cracking, embrittlement, holes and leaks.
- ❖ Failure to inspect frequently enough.
- ❖ Improper repair of a leak or other defect involving welding and annealing that embrittles and further weakens the vessel. Hazards posed by a vessel can be worse if repair welds are made without shutting down and de-inventorying the vessel. If a pressure vessel is repaired without removing the water, the quench effect of the water can embrittle the steel.
- ❖ Overpressuring and failure of the vessel due to exothermic reaction or polymerization.
- ❖ Vessel exposure to fire.

Pressure Vessel Laws

Requirements for pressure vessels vary widely from state to state. Many states have a boiler law, but others do not. Even for those states that have a boiler law, typical practices (e.g., inspector requirements) for pressure vessels may vary. State boiler laws that require general adherence to American Society of Mechanical Engineers (ASME) codes or National Board Inspection Code (NBIC) usually require the following for each pressure vessel:

- ❖ Registering with the state boiler and pressure vessel department.
- ❖ Designing and constructing in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code (ASME Code), Rules for Construction of Pressure Vessels, Division 1, which covers vessels operating between 15 psi and 3000 psi.
- ❖ Marking the ASME Code on the vessel with

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specified information that includes the manufacturer, the serial number, the year built, and the maximum allowable working pressure for a specific temperature, and any special suitability such as for low temperature and poisonous gases or liquids.

- ❖ Having the vessel approved for installation with the submission of drawings, specifications, welding details and calculations, and having an authorized inspector be satisfied with the welding and witness the testing.
- ❖ Operating at pressures below the maximum allowable working pressure with pressure relieving devices set according to the ASME Code; testing at regular intervals.
- ❖ Periodically inspecting for corrosion and defects, and testing according to the NBIC Manual for Boiler and Pressure Vessel Inspectors or American Petroleum Institute (API) 510, "Pressure Vessel Inspection Code," for vessels in the petrochemical industry.
- ❖ Repairing or altering only according to a plan approved by an authorized inspector and conducted by test-qualified welders. The inspector must be satisfied that the repairs are performed according to NBIC or API 510 and specify any necessary nondestructive and pressure testing. Increasing the maximum allowable working pressure or temperature is considered an alteration whether or not physical work is done.

In states with no pressure vessel law, good safety practices require that similar precautions be followed in the design, construction, welding, testing, marking, operation, inspection, and repair of any pressure vessel. The ASME Code should be used for the design, construction, initial testing, and operation of pressure vessels. The NBIC or API 510 should be used for maintenance and inspection and subsequent testing. Boiler and machinery insurance companies, some pressure vessel suppliers, or jurisdiction-licensed independent contractors can provide authorized inspectors.

Evaluating Potential Explosion Hazard

Facilities, particularly those without formal pressure vessel inspection programs, should survey their vessels, review pertinent history and data to identify hazards, and prevent vessel rupture or catastrophic failure.

Among the questions to be asked and answered are the following:

- 1) Does the vessel operate above 15 psi, and was it designed, fabricated, and constructed according to the ASME Code or other applicable code?
Is the vessel code labeled or stamped?
Is the operating pressure and size of the vessel known?
- 2) Is the vessel maintained, inspected, and repaired according to the NBIC and/or API 510?
- 3) Are the ratings and settings of the relieving devices appropriate?
Are the devices tested regularly and how recently?
- 4) Is the vessel inspected periodically?
What are the criteria for inspection frequency?
When was it last inspected externally?
When was it last inspected internally?
Did the inspection disclose general thinning of walls due to corrosion, localized corrosion, stress corrosion cracking, embrittlement, holes, leaks, or any other defects that required follow up?
Were they followed up?
- 5) Has the vessel been repaired?
Were the plan of repair, welding techniques and safety tests approved by a certified or authorized inspector?
Was the welding done by a qualified welder?
Were the welding performance qualification tests approved by an inspector?
Was the vessel tested after the repair was completed?
- 6) Was the vessel down rated and were the necessary changes in operating conditions and relief device settings made?
- 7) Are exothermic reactions carried out in the vessel?
Does the vessel have an emergency relief system to handle runaway reactions?

(Reference: EPA Publication 550-F-97-002A)

Case History: Faulty Welds Caused Pressure Vessel Explosion and Fire

This incident provides information regarding an explosion and fire that occurred at the Marcus Oil facility in Houston, Texas in December 2004. Investigators determined that the explosion resulted from faulty welds in a steel process pressure vessel.



The scene following the explosion

o Discussion

In its final investigation report on the explosion, the U.S. Chemical Safety Board (CSB) describes the violent explosion of a 50,000-pound steel pressure vessel at the Marcus Oil and Chemical facility. The explosion was felt over a wide area in Houston and ignited a fire that burned for seven hours. Several residents were cut by flying glass.

Building and car windows were shattered, and nearby buildings experienced significant structural and interior damage.

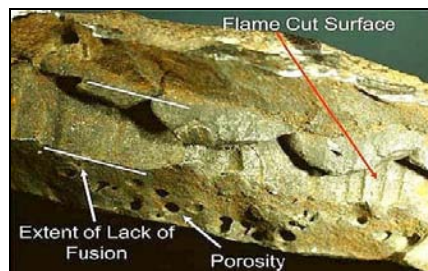
The Marcus Oil facility refines polyethylene waxes for industrial use. The crude waxes, which are obtained as a byproduct from the petrochemical industry, contain flammable hydrocarbons such as hexane. The waxes are processed and purified inside a variety of steel process vessels. The vessel that exploded was a horizontal tank 12 feet in diameter, 50 feet long, and operated at a pressure of approximately 67 pounds per square inch.

The case study report and accompanying safety recommendations have been posted to the CSB web site (<http://www.csb.gov>).

o Welding Issues

Investigators determined that the failed vessel, known

as Tank 7, had been modified by Marcus Oil to install internal heating coils, as were several other pressure vessels at the facility. Following coil installation, each vessel was resealed by welding a steel plate over the 2-foot-diameter temporary opening. The repair welds did not meet accepted industry quality standards for pressure vessels. Marcus Oil did not use a qualified welder or proper welding procedure to reseat the vessels and did not pressure-test the vessels after the welding was completed.



Recovered patch plate weld from failed Tank 7

The weld used to close the temporary opening on Tank 7 failed during the incident because the repair weld (see figure) did not meet generally accepted industry quality standards for pressure vessel fabrication. The original, flame-cut surface was not ground off the plate edges before the joint was re-welded, and the weld did not penetrate the full thickness of the vessel head. Furthermore, the welds contained excessive porosity (holes from gas bubbles in the weld). These defects significantly degraded the strength of the weld.

o Design Issues – Relief Valves

Investigators found that Tanks 5, 6, 7, and 8, the nitrogen storage vessels, and the compressed-air storage vessel were not equipped with pressure-relief devices, as required by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. However, this was not a factor in causing the incident.

o Process Changes

Marcus Oil installed a connection between the nitrogen and compressed-air systems to provide rapid pressurization of the nitrogen system when the

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nitrogen pressure was too low to move molten wax from the tanks to the process unit. The company assumed that compressed air was an acceptable substitute for nitrogen during processing. However, investigators determined that management did not evaluate the hazards that resulted from this process change. Pressurizing the nitrogen system with compressed air contaminated the nitrogen gas with as much as 18 percent oxygen — a level sufficient to support combustion.

Marcus Oil used air instead of nitrogen to boost the pressure of the vessel, and the oxygen inside the tank allowed the ignition of the flammable material, most likely by sparks from the metal fragments. The fire spread back into the damaged tank and caused a violent explosion, which propelled the 25-ton vessel more than 150 feet.

o Pressure Vessel Codes

The ASME Boiler and Pressure Vessel Code provides

rules for pressure vessel design, fabrication, weld procedures, welder qualifications, and pressure testing. In addition, the National Board of Boiler and Pressure Vessel Inspectors has established the National Board Inspection Code for pressure vessel repairs and alterations. The code requires alterations to pressure vessels to be inspected, tested, certified, and stamped.

"If the provisions of internationally recognized pressure vessel safety codes had been required and enforced, this accident would almost certainly not have occurred," CSB Board Member John S. Bresland said.

o Implications

The incident at the Marcus Oil facility underscores the importance of compliance with pressure vessel and inspection codes and the use of qualified welders. Equally important is understanding the potential hazards introduced with process changes.

(References: CSB; DOE/Richard Higgins)

Process Safety Information for Pressure Vessels and other Process Equipment

The EPA Risk Management Program (RMP) requires the facility to complete a compilation of written process safety information This process safety information shall include information pertaining to the hazards of the regulated substances used or produced by the process, information pertaining to the technology of the process, and information pertaining to the **equipment in the process**. (40 CFR 68.65.)

For equipment in the process, you must include information on:

- ✓ Materials of construction
- ✓ Piping and instrument diagrams (P&IDs)
- ✓ Electrical classification
- ✓ Relief system design and design basis
- ✓ Ventilation system design
- ✓ Design codes & standards employed
- ✓ Safety systems
- ✓ Material and energy balances for processes built after June 21, 1999

Pressure Vessel Hazard Reduction

Pressure vessels must comply with all regulations, industry codes, and standards to keep vessels in safe condition to handle design pressures and temperatures. Areas to review could include, but are not limited to, the following:

Design

At a minimum, pressure vessels should be designed in accordance with the American Society of Mechanical Engineers (ASME) Code for material contents of varying characteristics. Facilities should address any added concerns about the temperature and characteristics of vessel contents (e.g., toxic, corrosive, reactive, or flammable contents). When the vessel contents are changed from those the vessel as designed for, a risk analysis should be conducted to determine if it is still safe for the new materials.

Certification of Vessels

Many states have a boiler law, but others do not. In states with a pressure vessel law, all pressure vessels must be certified by the relevant state authority as meeting requirements of the ASME Code. When a pressure vessel cannot be constructed to comply fully with the ASME Code, however, the National Board Inspection Code (NBIC) provides a procedure by which the pressure vessel may get state approval without bearing the ASME symbol. This procedure includes submittal of drawings, calculations, welding procedures, service conditions, welding qualification and performance tests, and professional engineering certifications. This should be done before any construction begins.

When a facility finds an unmarked vessel or is about to bring one into a state, similar information plus the repair history should be submitted to the state pressure vessel authority for review and approval before use begins or continues.

On the other hand, when a pressure vessel is located in a state without a pressure vessel law, is not marked with the ASME symbol, and there are doubts about the safety of the vessel, the information listed above should be submitted to a pressure vessel consulting engineer and authorized inspector for a safety review.

Inspection of Vessels

The NBIC and American Petroleum Institute (API) 510 require that vessels be periodically inspected externally and internally. External inspections are made more frequently and involve visual and nondestructive examination. An internal inspection is more difficult to perform because it usually requires a confined space entry and the vessel must be taken out of service, cleaned, and prepared. General or localized thinning of the internal walls due to corrosion or erosion is a potential problem and must be monitored, with records kept of the rate of thinning. When the vessel is reaching the end of its useful life, the period between inspections is shortened so that the vessel may be taken out of service before it can become dangerous. An internal test may also reveal stress corrosion, cracking, pitting, embrittlement, and other defects that could weaken the vessel. In addition to the vessel itself, the relieving devices must also be tested. When practical, this can be done in place for vessels containing non-hazardous substances, but for vessels containing hazardous substances without special controls (e.g., scrubbers), safety relief valves must be taken off to ascertain whether their settings are correct. How this can be done safely and conveniently should be considered.

Maintenance

In addition to maintenance requirements, the NBIC and API 510 include specific preheating and postheating requirements. Large temperature differences between the outside and inside surfaces of the vessel - during repair or other welding - must be avoided to minimize embrittling or stressing the metal. Nondestructive examinations may include radiographic, ultrasonic, liquid penetrant, magnetic particle, eddy current, visual checks, and leak testing.

Operation of Vessels

Operators should consider process start-up and shutdown conditions, possible process upsets, and any other unusual conditions that might cause overpressure problems. The ASME Code includes recommended pressure differentials between safety valve set pressures and maximum allowable working pressure, as well as the pressure differential settings of the relieving devices when there are multiple devices.

(Reference: EPA)

Atmospheric Tank is Not a Pressure Vessel!

On June 21, 2001, a worker died when a 500-gallon atmospheric storage tank he was emptying of waste oil and water exploded from its base. He was pressurizing the contents of tank using compressed air to speed up draining. Compressed air at 120 psi was used. The tank was not approved for use as a pressurized vessel. According to a co-worker, the practice of pressurizing the tank had been going on for 6 years without management's awareness. The procedure had been passed from maintenance worker to maintenance worker.

The force of the explosion propelled the tank 500 feet in the air over the plant fence and a nearby bank parking lot onto a busy road. The event resulted in OSHA issuing one serious citation under the General Duty Clause for failing to establish, train on and enforce use of a procedure to empty waste oil containers which would prohibit application of air pressure to a container not designed or rated as a pressure vessel.

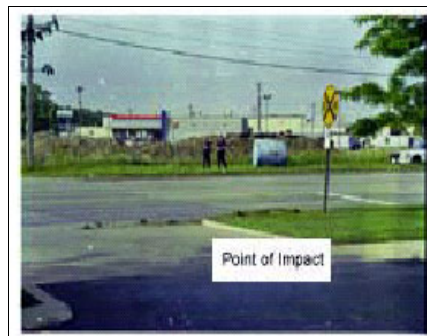
What Can You Do

- ✚ **Conduct job safety analyses and establish standard operating procedures for routine maintenance tasks and train the maintenance personnel in these procedures.**

A job hazard analysis is a procedure used to review each job, identify potential hazards, and design actions and procedures to eliminate or control the hazards. Input from workers who usually perform the tasks is important. Of primary importance is the recognition that hazards exist. Even though maintenance work is complex and constantly changing, there are routine tasks. The transferring of waste oil and water was a routine task. A job hazard analysis may have identified the potential for employee injury pressurizing a tank that was not approved as a pressurized vessel.

- ✚ **Do not pressurize a container not approved as a pressure vessel.**

This fatality involved the improper use of equipment. The task was commonly conducted, yet no one associated with the practice was aware of the consequences of pressurizing a vessel not approved for use under pressure. OSHA has regulations regarding the use and inspection of pressure vessels. ASME, the Compressed Gas Association, and the American Petroleum Institute among others have standards and guidelines governing the use of pressure vessels.



- ✚ **Train maintenance personnel to anticipate conditions that could jeopardize their safety or the safety of others.**

A Maintenance Supervisor indicated he did not know pressurizing the tank was a dangerous practice or that anything could go wrong. Working with pressurized equipment requires a level of care and engineering knowledge which was not available in the Maintenance Department. Maintenance workers need safety training because they are continually presented with a complex and constantly changing set of activities. Maintenance workers travel throughout the entire plant in the course of their work. Properly trained, they can provide information that is beneficial to the other plant activities while conducting their work.

- ✚ **Inform employees that no equipment is to be altered or retrofitted. Establish a procedure for a qualified person(s) to review proposed equipment changes. Conduct periodic plant audits specifically for non-standard use of equipment.**

When equipment is retrofitted, altered or used in a way for which it was not designed or for a purpose other than originally intended, unintentional consequences may result. A procedure for a qualified person(s) to review equipment change, modification or use should be developed and implemented. Since there is always pressure to "make do" with what is at hand or adapt what is available, periodic plant audits to detect unapproved equipment change or modification should be conducted.

(Reference: MSU)

Safety Alert

Liquefied Gas Cylinder Failure



Intact cylinder and remains of ruptured cylinder

A liquid nitrogen cylinder in a university chemistry laboratory catastrophically failed due to over pressurization, causing substantial damage. Fortunately the incident occurred at 3 AM and the building was not occupied, so there were no injuries. The over pressurization blew out the bottom of the cylinder and propelled the cylinder upwards. The cylinder pressure relief valve and rupture disc had been replaced by two brass plugs at some time in the past by an unknown person. Before the incident, the cylinder may have been leaking through an old gasket, providing sufficient release of gas to prevent over pressure.



Laboratory Damage

Approximately twelve hours before the explosion, the leaking gasket had been replaced and the cylinder refilled with liquid nitrogen. With the new gasket, the cylinder was now completely sealed, and pressure could build up. The cylinder ruptured when its internal pressure rose above 1000 psi. The catastrophic failure of the nitrogen cylinder was a result of the removal of the pressure relief devices.

Did you know?

- Liquefied and pressurized gas cylinders are commonly used in laboratories and in manufacturing plants.
- In this incident, the force released by the failure of the cylinder was estimated at 250,000 pounds (~ 113,000 kilogramsforce).
- Cryogenic storage must either be refrigerated to maintain the low temperature and pressure, or slowly bleed off enough vapor to maintain pressure and cool the remaining inventory.
- An incident this powerful can release other hazardous materials in nearby containers, vessels, and piping, causing an even more severe incident.

What can you do?

- Never modify any equipment containing hazardous materials or energy without qualified engineering evaluation, and always conduct a management of change review.
- If you observe a high pressure or liquefied gas cylinder that appears to have been modified, or is corroded or otherwise damaged, report it to supervision immediately so it can be removed from service.
- Ensure that cylinders are properly maintained and periodically inspected, including the pressure relief devices.
- If you use pressurized gas cylinders, make sure you are properly trained in the safe handling of high pressure cylinders.
- Share this incident with your colleagues in the laboratory who may use pressurized gas cylinders.

(Reference: Process Safety Beacon)

This newsletter provides information on the EPA Risk Management Program, EPCRA and other issues relating to the Accidental Release Prevention Requirements of the Clean Air Act. The information should be used as a reference tool, not as a definitive source of compliance information. Compliance regulations are published in 40 CFR Part 68 for CAA section 112(r) Risk Management Program, and 40 CFR Part 355/370 for EPCRA.

RISK MANAGEMENT PROGRAM (RMP) TRAINING – PORTLAND, OR – JUNE 3, 4, 5

Section 112(r) of the Clean Air Act mandates that facilities that hold or use very toxic or flammable substances at or above threshold quantities develop Risk Management Programs. The Environmental Protection Agency (EPA) is offering FREE one-day RMP Training, which will provide information about how to comply with the RMP reporting and emergency planning requirements.

This one-day training is being offered three separate days. Information can be found at (<http://yosemite.epa.gov/R10/CLEANUP.NSF/sites/rmp>). To register or for more information contact: allen.stephanie@epa.gov

REGULATORY UPDATES**Department of Homeland Security Chemical Facility Anti-Terrorism Standards (CFATS) do not impact EPCRA or CAA 112(r) Reporting**

In a new regulation (6 CFR Part 27) the Department of Homeland Security (DHS) began (January 22, 2008) requiring vulnerability assessment and security planning for locations that store hazardous chemicals. Inclusion under the regulation is dependent upon the type and amount of chemicals stored. The thresholds for inclusion are generally lower than other regulatory programs.

Recently, several facilities subject to Federal reporting requirements under the Emergency Planning and Community Right to Know Act (EPCRA) or Clean Air Act section 112(r) have inquired about the appropriateness of filing reports under these legislative requirements. Facilities have cited nondisclosure or confidentiality agreements relating to implementation of the Department of Homeland Security's new Chemical Facility Anti-Terrorism Standards (CFATS).

It should be noted that nothing in the new CFATS regulations alters the requirements that apply to a

facility covered under both CFATS, EPCRA and CAA 112(r).

In the preamble to the regulation, DHS further clarifies this provision, specifically indicating that CFATS has no affect on EPCRA, CAA section 112(r), and other laws administered by EPA:

"At this time, we do not intend to displace or otherwise affect any provisions of Federal statutes, including the Emergency Planning and Community Right to Know Act, 42 U.S.C. 11001 et seq., or section 112(r) and 114 of the Clean Air Act of 1990, as amended."

The regulation and preamble language are consistent with similar language contained in the statute authorizing the CFATS program (Public Law 109-295, Section 550).

At the headquarters level, EPA and DHS officials have had recent discussions to confirm that the current intent of the CFATS regulations remains in accordance with this understanding and that information currently required to be submitted under EPCRA and CAA Section 112 (r) is not Chemical-Terrorism Vulnerability Information (CVI).

Tier 2 Annual Reports Were Due March 1

Tier 2 annual reports were due March 1, 2008. State reporting requirements are available at <http://www.epa.gov/emergencies/content/epcra/tier2.htm>